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ASSESSING MATERIAL NONLINEARITIES IN LARGE COMPOSITE STRUCTURES BY PREDICTING ENERGY DISSIPATIONS AT THE MESOSCALE

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Composite materials represent multi-hierarchical systems where effects at several length scales control the overall material behaviour. Nonlinearities such as damage and plasticity typically arise at smaller length scales and their consideration necessitates models of the meso- or microstructure of a given composite. Analyses of this type are feasible for small computational domains (e.g. unit cells), however, incorporating multiple length scales into large structural analyses, as done in approaches like FE^2, requires huge computational resources. The present paper introduces a methodology which aims at reducing computational cost of large scale analyses by accounting for nonlinearities in an approximate way. To this end, linear elastic structural simulations are interpreted with recourse to results from nonlinear simulations conducted at smaller length scales.

First, the small length scale (e.g. the length scale of a single woven ply) is considered by utilizing a unit cell based homogenization approach assuming plane stress conditions. Appropriate constitutive models for the composite tows are applied to predict the occurrence of damage and plasticity. The quantitative extent of these nonlinearities is tracked by monitoring corresponding dissipated energies with respect to the loading history. On the basis of this modelling strategy simulations of radial load paths are conducted in order to generate a database of dissipated energy fractions with sufficient resolution. Mapping states of these unit cell simulations onto linear elastically computed states allows for associating dissipated energies. This way an approximate assessment of nonlinearities can be conducted on the basis of a material specific database and linear elastic simulations, cf. [1].

According to this methodology, the initiation of nonlinearities can be interpreted in a similar way as first ply failure criteria. Considering the evolution of dissipated energies with respect to further load increase the severeness of occurring stress states can be estimated, thus, extending predictive capabilities beyond the linear elastic limit. The validity of the underlying approximation can be verified by comparing unit cell simulations of radial stress and strain paths. The whole methodology is applied as a post processing step of linear elastic analyses and can be conducted very efficiently once a database for the considered material has been generated.

The described procedure is illustrated by the example of a structural component consisting of $\pm 30°$ biaxial braidings, where a shell element based unit cell approach is used to model the braid behaviour, cf. [2]. The presented procedure shows good applicability up to moderately nonlinear regimes, thus, giving information beyond the linear elastic limit and allows for a more detailed investigation of the mechanical performance of large composite components.

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REFERENCES

[1] M. Schwab. *Prediction of energy dissipation due to material nonlinearities and its application to textile composites. Master's thesis.* Institute of Lightweight Design and Structural Biomechanics, Vienna University of Technology, 2013.

[2] J. Gager and H.E. Pettermann. Numerical homogenization of textile composites based on shell element discretization. *Composites Science and Technology*, Vol. **72**, 806–812, 2012.